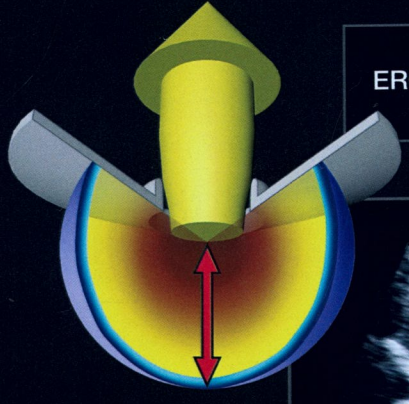
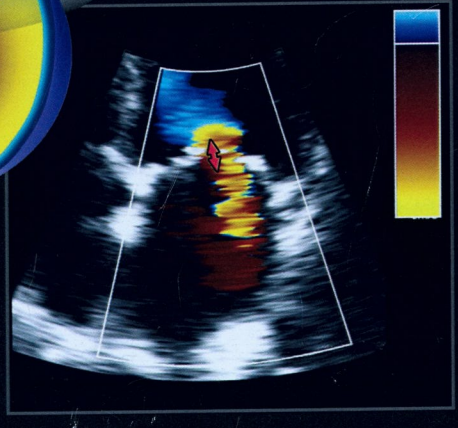
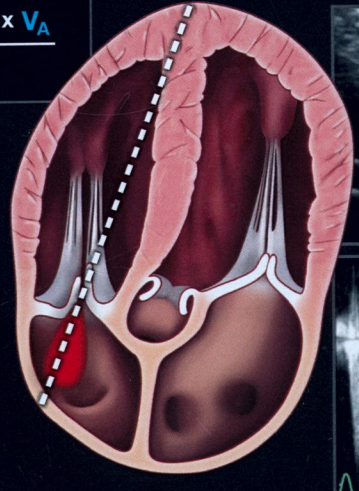
ASE American Society of Echocardiography

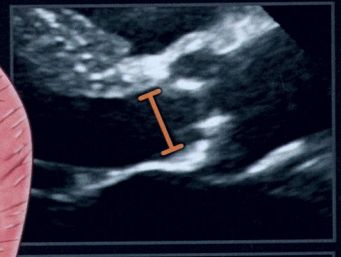
Echocardiography Formula Review Guide:
Native Valves and Intracardiac Pressures

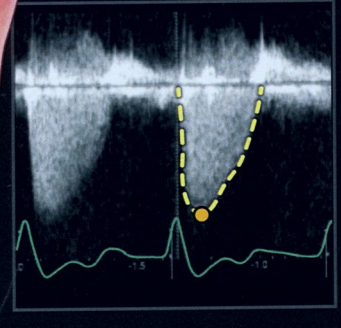


$$ERO = \frac{\text{Reg flow}}{V_{Max}} = \frac{2 \times \pi \times r^2 \times V_A}{V_{Max}}$$









SHOUT
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IT

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Steven Lester, MD, FASE; Hemalatha Narayanasamy, MBBS, MD;
Matthew W. Parker, MD, FASE; Brent White, MD.

Adapted from:

Echocardiographic Assessment of Valve Stenosis: EAE/ASE Recommendations for Clinical Practice. J Am Soc Echocardiogr 2009; 22: 1-23.

Recommendations for Noninvasive Evaluation of Native Valvular Regurgitation: A Report from the American Society of Echocardiography Developed in Collaboration with the Society for Cardiovascular Magnetic Resonance. J Am Soc Echocardiogr 2017; 30: 303-371.

Recommendations on the Echocardiographic Assessment of Aortic Valve Stenosis: A Focused Update from the European Association of Cardiovascular Imaging and the American Society of Echocardiography. J Am Soc Echocardiogr 2017; 30: 372-392.

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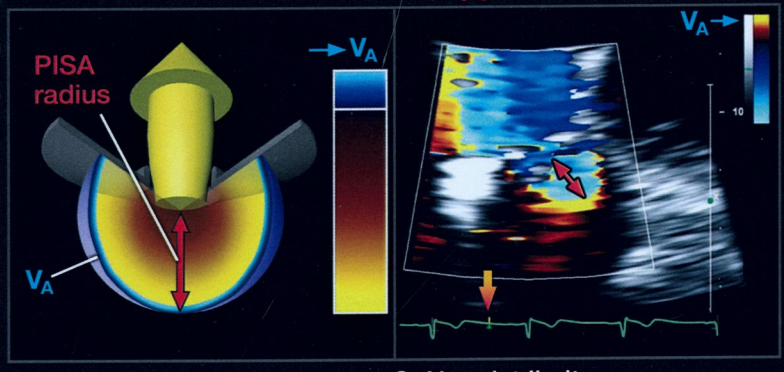
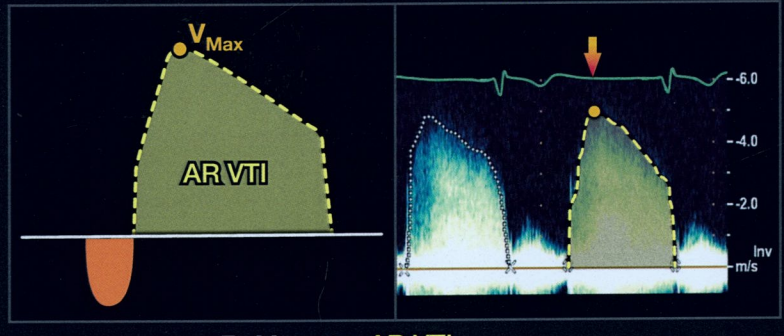
Aortic Regurgitation: Flow Convergence Method (PISA)

Color Flow Doppler



A. Align beam
B. Zoom
C. Nyquist limit →
D. Draw radius ↕

Aortic Valve CW Doppler



F. Measure AR VTI
G. Measure AR Max Velocity

r = Radial distance from orifice (cm)
V_A = Aliasing velocity at radial distance (r) (cm/s)
V_{Max} = Peak velocity of AR jet (cm/s)
↕ = Note: the PISA radius (r) is to be measured at the same time point in the cardiac cycle as V_{Max}
VTI = VTI of AR jet (cm)
ERO = Effective regurgitation orifice area (cm^2)
RVol = Regurgitant volume (mL/beat)
RF = Regurgitant fraction (%)

$$PISA = 2 \times \pi \times r^2$$

$$\text{Regurgitant flow} = 2 \times \pi \times r^2 \times V_A$$

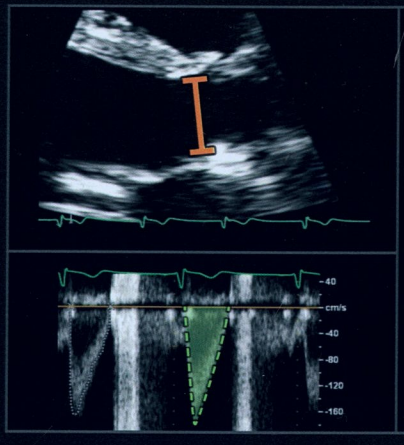
$$ERO = \frac{\text{Reg flow}}{V_{Max}} = \frac{2 \times \pi \times r^2 \times V_A}{V_{Max}}$$

$$RVol = ERO \times VTI \qquad RF = \frac{RVol}{\text{LVOT stroke volume}}$$

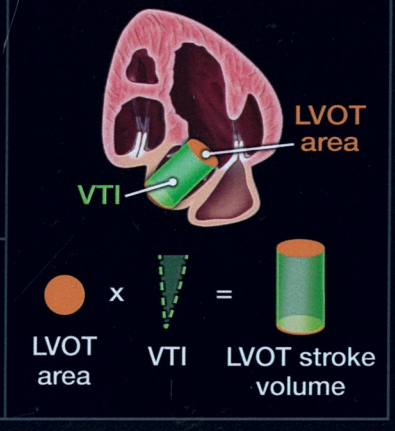
	Mild	Moderate	Severe
EROA (cm^2)	< 0.10	0.11 - 0.29	≥ 0.30
RVol (mL)	< 30	30 - 59	≥ 60
RF (%)	< 30	30 - 49	≥ 50

Aortic Regurgitation: Continuity Method

LVOT Diameter



LVOT Stroke Volume



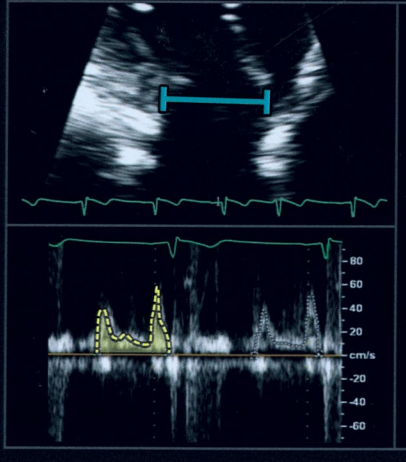
LVOT diameter in mid systole (cm)
PW Doppler at LVOT (VTI) (cm)
MV annulus diameter in mid diastole (cm)
PW Doppler at the level of MV annulus (VTI) (cm)
EROA = Effective regurgitation orifice area (cm^2)
RVol = Regurgitant volume (mL/beat)
RF = Regurgitant fraction (%)

RVol = LVOT SV – Mitral valve SV

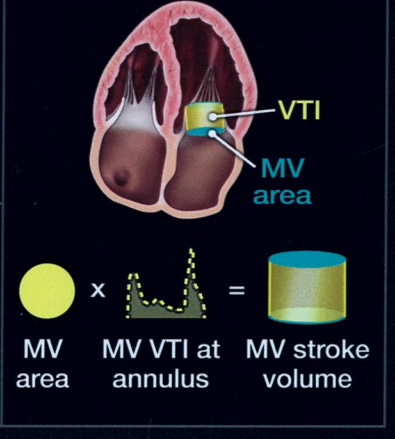
RVol = (LVOT area x LVOT VTI)
– (MV area x MV VTI)

$$RVol = \left\{\pi \times \left(\frac{\text{LVOT diameter}}{2}\right)^2 \times \text{LVOT VTI}\right\} - \left\{\pi \times \left(\frac{\text{MV annulus diameter}}{2}\right)^2 \times \text{MV VTI}\right\}$$

MV Annulus Diameter



Mitral Valve Stroke Volume

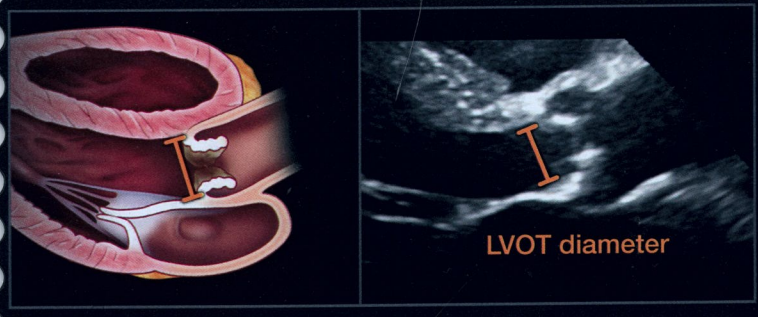


$$EROA\ (cm^2) = \frac{RVol}{AR\ VTI} \qquad RF\ (\%) = \frac{RVol}{LVOT\ SV}$$

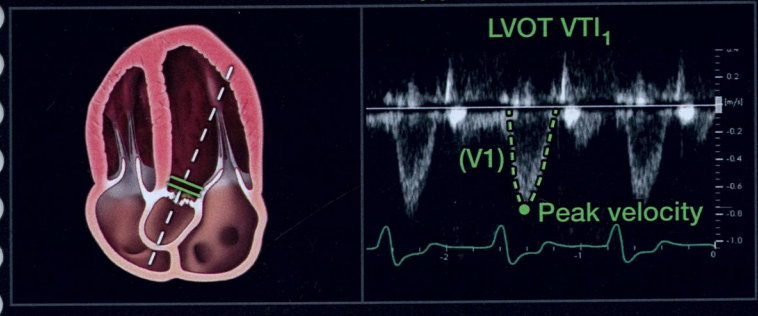
	Mild	Moderate	Severe
EROA (cm^2)	< 0.10	0.11 - 0.29	≥ 0.30
RVol (mL)	< 30	30 - 59	≥ 60
RF (%)	< 30	30 - 49	≥ 50

Aortic Stenosis

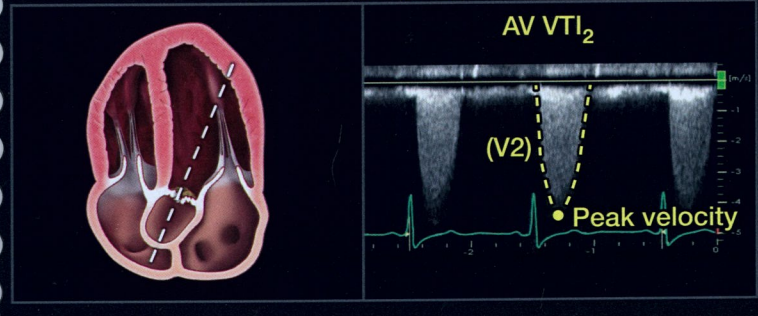
LVOT Diameter



LVOT PW Doppler

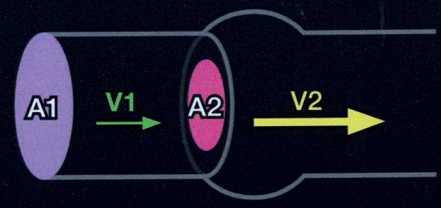


AV CW Doppler



$$A1 \times V1 = A2 \times V2$$

$$A2 = \frac{A1 \times V1}{V2}$$



$A1$ = LVOT area (cm^2) $A2$ = AV area (cm^2)

VTI_1 = LVOT VTI (cm) VTI_2 = AV VTI (cm)

$$\text{AV area} = \frac{\text{LVOT area} \times \text{LVOT VTI}}{\text{AV VTI}}$$

$$\text{AV area} = \frac{\pi \times \left(\frac{\text{LVOT diameter}}{2}\right)^2 \times \text{LVOT VTI}}{\text{AV VTI}}$$

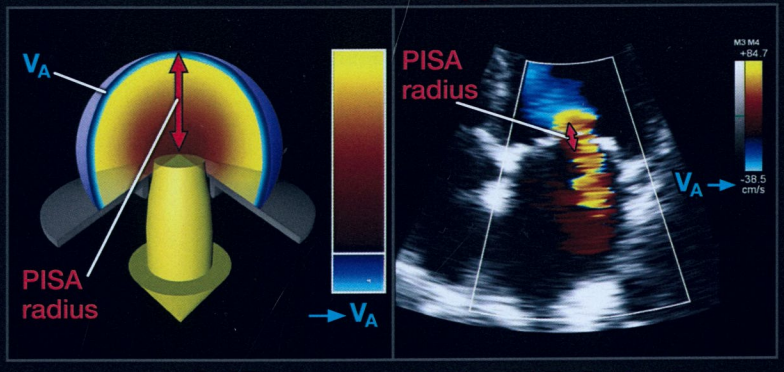
Velocity time integral ratio (dimensionless index) $= \frac{\text{LVOT VTI}}{\text{AV VTI}}$

Grading AS Severity

	Mild	Moderate	Severe
Peak velocity (m/s)	2.6 - 2.9	3.0 - 4.0	≥ 4.0
Mean gradient (mmHg)	< 20	20 - 40	≥ 40
AVA (cm^2)	> 1.5	1.0 - 1.5	< 1.0
Indexed AVA (cm^2/m^2)	> 0.85	0.60 - 0.85	< 0.6
Dimensionless index	> 0.50	0.25 - 0.50	< 0.25

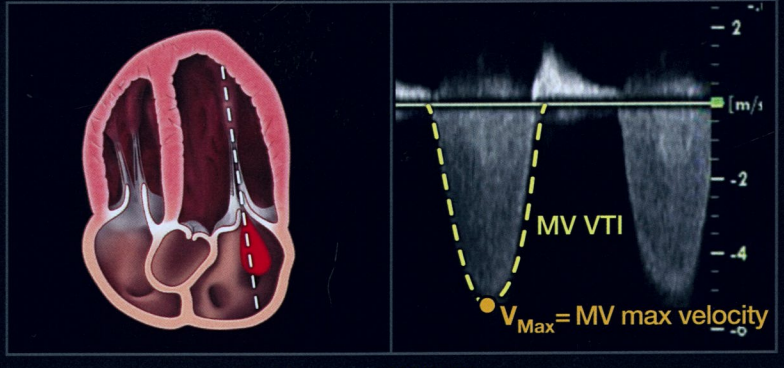
Mitral Regurgitation: Flow Convergence Method (PISA)

Color Flow Doppler



A. Align beam
B. Zoom
C. Variance off
D. Nyquist limit →
E. Draw radius ↕

MV CW Doppler



F. Measure MV VTI
G. Measure MV max velocity

r = Radial distance from orifice (cm)
V_A = Aliasing velocity at radial distance (r) (cm/s)
V_{Max} = Peak velocity of MR jet (cm/s)
VTI = VTI of MR jet (cm)
ERO = Effective regurgitant orifice (cm^2)
RVol = Regurgitant volume (mL/beat)
RF = Regurgitant fraction (%)

$$PISA = 2 \times \pi \times r^2$$

$$\text{Regurgitant flow} = 2 \times \pi \times r^2 \times V_A$$

$$ERO = \frac{\text{Reg. flow}}{V_{Max}} = \frac{2 \times \pi \times r^2 \times V_A}{V_{Max}}$$

$$RVol = ERO \times VTI \qquad RF = \frac{RVol}{\text{Stroke volume}^*}$$

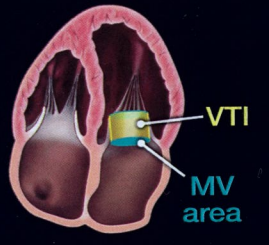
* Calculated as forward stroke volume (either using transmitral inflow or the sum of LVOT flow and RVol)

	Mild	Moderate	Severe
EROA (cm^2)	< 0.20	0.20 - 0.39	≥ 0.40
RVol (mL)	< 30	30 - 59	≥ 60
RF (%)	< 30	30 - 49	≥ 50

Mitral Regurgitation: Continuity Method

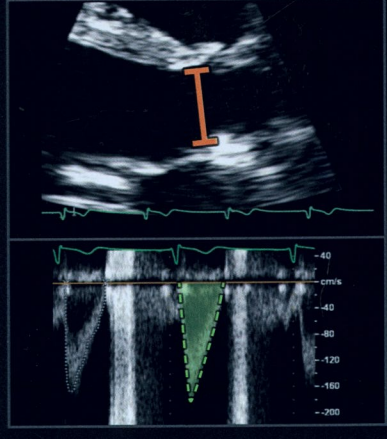
MV Annulus Diameter

Mitral Valve Stroke Volume

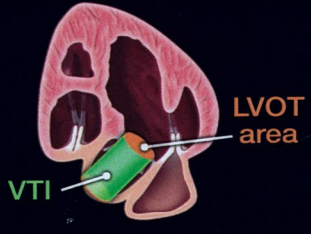


MV area x MV VTI at annulus = MV stroke volume

LVOT Diameter



LVOT Stroke Volume



LVOT area x VTI = LVOT stroke volume

LVOT diameter in mid systole (cm)
PW Doppler at LVOT (VTI) (cm)
MV annulus diameter in mid diastole (cm)
PW Doppler at the level of MV annulus (VTI) (cm)
EROA = Effective regurgitation orifice area (cm^2)
RVol = Regurgitant volume (mL/beat)
RF = Regurgitant fraction (%)

RVol = Mitral valve SV – LVOT SV

RVol = (MV area x MV VTI) – (LVOT area x LVOT VTI)

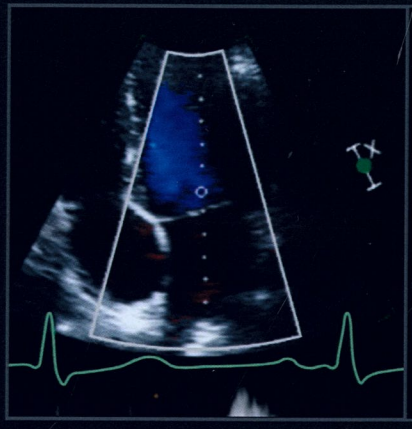
$$RVol = \left\{\pi \times \left(\frac{\text{MV annulus diameter}}{2}\right)^2 \times \text{MV VTI}\right\} - \left\{\pi \times \left(\frac{\text{LVOT diameter}}{2}\right)^2 \times \text{LVOT VTI}\right\}$$

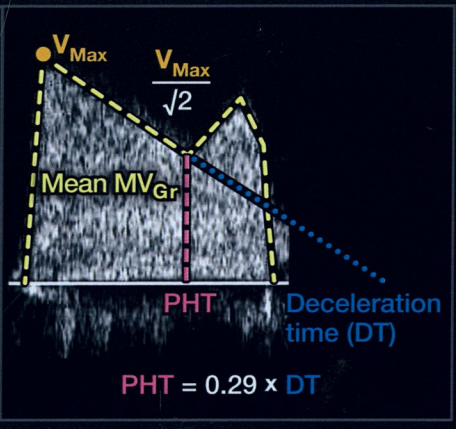
$$EROA\ (cm^2) = \frac{RVol}{MR\ VTI} \qquad RF\ (\%) = \frac{RVol}{MV\ SV}$$

	Mild	Moderate	Severe
EROA (cm^2)	< 0.20	0.20 - 0.39	≥ 0.40
RVol (mL)	< 30	30 - 59	≥ 60
RF (%)	< 30	30 - 49	≥ 50

Mitral Stenosis

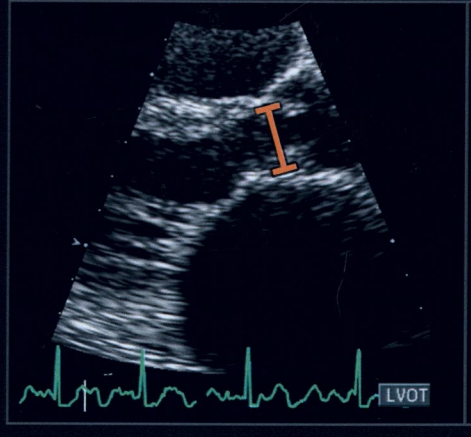
Continuous Flow Doppler



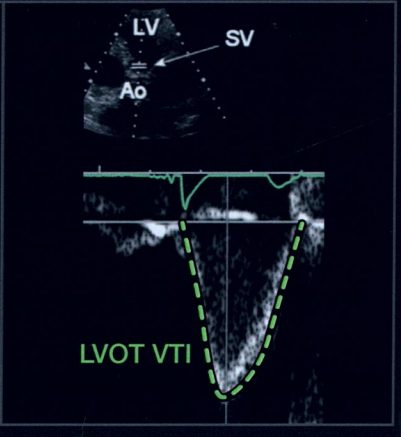


PHT = 0.29 x DT

LVOT Diameter



Pulsed Wave Doppler of the LVOT



Mean Mitral Valve Gradient (MV_{Gr})

Obtained by tracing Mean MV_{Gr} (mmHg) from the mitral valve continuous flow Doppler.

- Valid for HR 60-80 bpm
- Average multiple cardiac cycles (5 - 10) in atrial fibrillation

Pressure Half Time (PHT)

$$MVA\ (cm^2) = \frac{220}{PHT}$$

PHT validated in rheumatic mitral stenosis and less accurate in calcific mitral stenosis, atrial septal defect, significant aortic regurgitation, altered ventricular compliance (diastolic dysfunction), or after mitral balloon valvuloplasty.

Continuity Equation: $SV_{LVOT} = SV_{MV}$

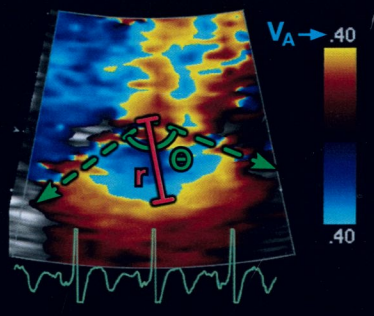
$$LVOT_{Area} = \pi \times \left(\frac{\text{LVOT diameter}}{2}\right)^2$$

$$MVA\ (cm^2) = LVOT_{Area} \times \frac{\text{LVOT VTI}}{\text{MV VTI}}$$

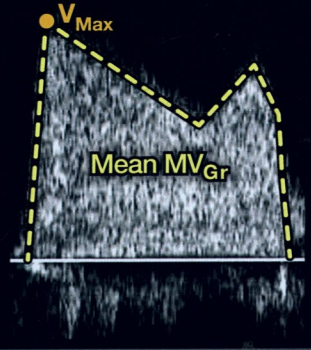
Assumes stroke volume through mitral valve is equal to stroke volume through LVOT. Inaccurate if either significant aortic or mitral regurgitation.

Mitral Stenosis

Color Flow Doppler



Continuous Flow Doppler



r = Radial distance from orifice (cm)

V_A = Aliasing velocity at radial distance (r) (cm/s)

V_{Max} = Peak velocity of MS jet (m/s)

Mean MV_{Gr} = Mean mitral valve gradient (mmHg)

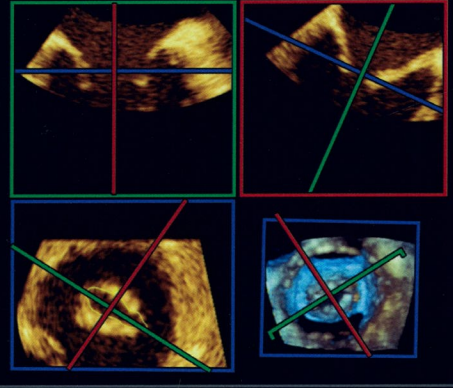
Θ = Angle of funnel shaped MV orifice

Planimetry 2D

Parasternal short axis view

Planimetry 3D

Direct tracing of the MV orifice including opened commissures at the MV leaflet lips in mid diastole.



$$\text{PISA flow rate} = 2\pi r^2 \times V_A$$

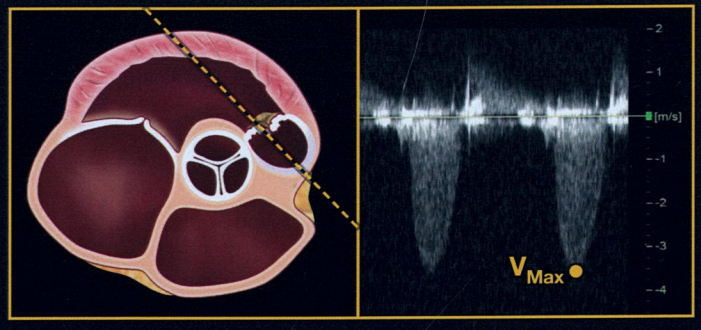
$$\text{MVA} = \frac{\text{PISA flow rate}}{V_{Max}} \times \frac{\Theta}{180}$$

Grading MS Severity

	Mild	Severe
Mean MV_{Gr} (mmHg)	< 5	> 10
PHT (ms)	145 - 150	> 220
MVA (cm^2)*	> 1.5 - 4.0	< 1.0

* MVA can be calculated by planimetry, continuity equation, or by PISA.

Pulmonic Stenosis

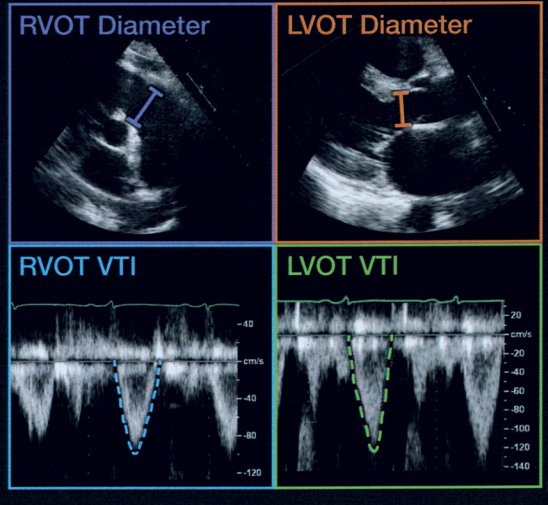


PV CW Doppler : $\Delta P_{Max} = 4(PV\ V_{Max})^2$

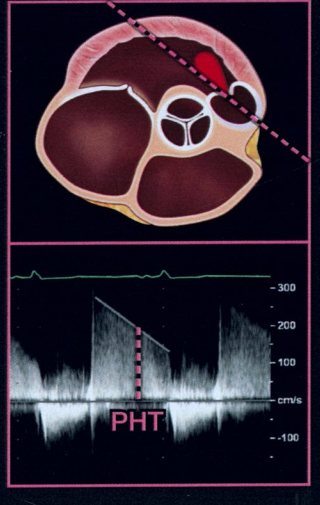
	Mild	Moderate	Severe
Peak Velocity (m/s)	< 3	3 - 4	> 4
Peak Gradient (mmHg)	< 36	36 - 64	> 64

Pulmonic Regurgitation

Regurgitant Volume and Fraction



CW Doppler Pressure Half-Time (PHT)



$$SV_{RVOT} = \pi \times \left(\frac{\text{RVOT diameter}}{2}\right)^2 \times \text{RVOT VTI}$$

$$SV_{LVOT} = \pi \times \left(\frac{\text{LVOT diameter}}{2}\right)^2 \times \text{LVOT VTI}$$

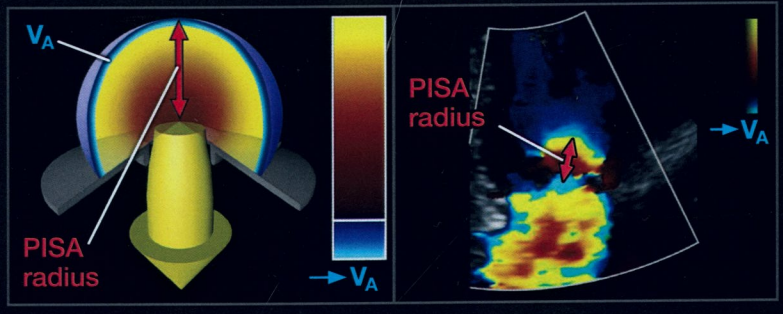
$$RVol\ (mL) = SV_{RVOT} - SV_{LVOT}$$

$$RF\ (\%) = \frac{RVol}{\text{Stroke volume}_{RVOT}}$$

Findings Suggestive of Severe PR	
PHT	< 100 ms
RF	> 40%

Tricuspid Regurgitation: Flow Convergence Method (PISA)

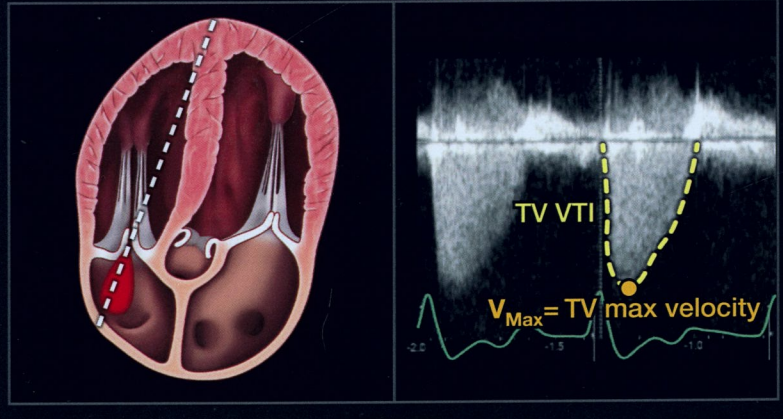
Color Flow Doppler



A. Align beam
B. Zoom
C. Variance off

D. Nyquist limit →
E. Draw radius ↕

TV CW Doppler



F. Measure TV VTI
G. Measure TV max velocity

r = Radial distance from orifice (cm)
V_A = Aliasing velocity at radial distance (r) (cm/s)
V_{Max} = Peak velocity of TR jet (cm/s)
VTI = VTI of TR jet (cm)
ERO = Effective regurgitant orifice (cm^2)
RVol = Regurgitant volume (mL/beat)

$$PISA = 2 \times \pi \times r^2$$

$$\text{Regurgitant flow} = 2 \times \pi \times r^2 \times V_A$$

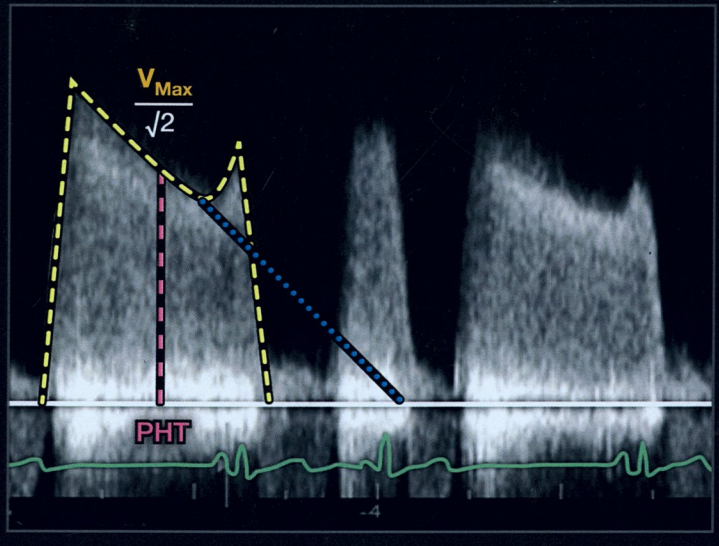
$$ERO = \frac{\text{Reg. flow}}{V_{Max}} = \frac{2 \times \pi \times r^2 \times V_A}{V_{Max}}$$

$$RVol = ERO \times VTI$$

	Mild	Severe
EROA (cm^2)	< 0.20	≥ 0.40
RVol (mL)	< 30	≥ 45

Tricuspid Stenosis

CW Doppler Through the Tricuspid Valve



Cut Off Values for Hemodynamically Significant Tricuspid Stenosis

Mean Gradient Pressure	≥ 5 mmHg
Pressure Half Time	≥ 190 ms
Inflow VTI	> 60 cm
Valve Area by Continuity Equation*	≤ 1 cm^2

* Use with caution as difficult to obtain accurate measurements of inflow volume through TV. In the absence of significant TR, one can use SV from either LVOT or RVOT.

Heart Pressures

Right Atrial Pressure (RAP)

RAP (mmHg)	0 - 5 (3)	5 - 10 (8)		10 - 20 (15)
IVC diameter (cm)	≤ 2.1	≤ 2.1	> 2.1	> 2.1
Collapse w/ sniff	> 50%	< 50%	> 50%	< 50%

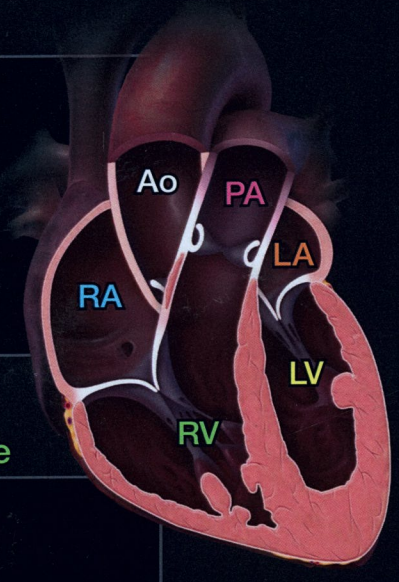
Mean Pulmonary Artery Pressure (mPAP)

$$mPAP = \frac{1}{3}PASP + \frac{2}{3}PADP$$

$$mPAP = 4(PR_{Peak\ velocity})^2 + RAP$$

$$mPAP = Mean\Delta P_{(RV\text{-}RA)} + RAP$$

$$mPAP = 79 - (0.45 \times RVOT\ AcT)$$



Right Ventricular Pressure

$$RVSP = 4(TRV_{Max})^2 + RAP$$

$$RVSP = SBP - 4(VSD_{Max})^2$$

$$RVEDP = LVEDP - 4(VSD_{Diastolic\ velocity})^2$$

Pulmonary Artery Pressure

$$PASP = RVSP\ (if\ no\ PS)$$

$$PASP = RVSP - PS_{Gradient}$$

$$PAEDP = 4(PR_{End\text{-}diastolic\ velocity})^2 + RAP$$

Pulmonary Vascular Resistance (PVR)

$$PVR = 10\ \frac{TR_{Peak\ systolic\ velocity}}{RVOT\ VTI} + 0.16$$

$$PVR = \frac{mPAP - mPCWP}{Cardiac\ output}$$

Left Atrial Pressure (LAP)

$$LAP = \frac{E}{e'} + 4$$

$$LAP = 1.24 \times \frac{E}{e'} + 1.9$$

$$LAP = SBP - 4(MR\ V_{Max})^2$$

Left Ventricle Pressure

$$LVSP = 4(MR_{Peak\ systolic\ velocity})^2 + LAP$$

$$LVEDP = DBP - 4(AR_{End\ diastolic\ velocity})^2$$

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asecho.org/guidelines

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ASEMarketPlace.com

ASE American Society of Echocardiography